Structural Usage Monitoring and Flight Regime Recognition Algorithm and Methodology Enhancement and Validation

Presented by

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The Team

- Richard "Pat" Anderson, ERAU, PI
- Andrew Kornecki, Ph.D., ERAU, Computer and Software Engineering.
- Several ERAU graduate students
- Systems and Electronics (SEI), industry partner
- Embry-Riddle's Eagle Works, flight-test facility

Objectives and Goals

The objective of this contract is to move a HUMS system for Usage Monitoring (UM) from a technology readiness level of 6 (system/subsystem prototype demonstration) to level 8 (operational qualified through test and demonstration).

In this case, the core prototype is SEI's Structural Integrity Monitoring System (SIMS).

The final (three year) goal is to qualify a variant of the SIMS, through test and demonstration, for UM under the guidance of AC-29-2C MG-15.

Project Overview

The scope of the contract is a three year effort for $621K equally spread over each year. This effort will result in the following research outputs:

1. A summary of the current state-of-the-art in structural usage monitoring and flight regime recognition algorithms.

2. An analysis of the current technology level (TRL) and capabilities of Commercial Off The Shelf (COTS) systems.

3. An analysis of the required level of technology to meet the certification guidance in AC 29-2C, Chg 1., MG 15.

Project Overview

4. A road map and design to determine the best course of action in moving from the current technology level to an AC 29-2C compliant system.

5. Manufacture of a demonstrator system that is AC 29-2C compliant.

6. Initial validation of the demonstrator unit in a flight environment and associated documentation.

Project Status

Currently in the first fiscal year with a start date of October 1st, 2005.

- Completed two intermediate reports on the following subjects:
  - Preliminary HUMS hazard assessment (end-to-end)
  - Architecture & configuration of the HUMS prototype system including airborne and ground-based station (GBS) units and software for flight
  - Aircraft level functional hazard assessment
  - Methodologies for addressing data collection discrepancies and compromised data integrity
  - Methodologies for electronically tracking rotorcraft components

Project Status

The first year has been characterized by cataloging the current HUMS technology level and understanding the implications of an end-to-end usage monitoring system for usage credits.

A simplified case of counting exceedances has been performed in an end-to-end case to determine hazard mitigation for usage credits in a a closed loop usage monitoring system.

This simplified case has been developed in parallel with the more detailed initial design of the software and hardware architecture of the airborne equipment and ground based (COTS) workstation.

Project Status

The team has just completed the top-level software and hardware requirements for the airborne equipment and ground based system. Analysis has shown that there are no top level show-stopper in the use of a modified SEI SIMS. Several key modification, however, have been determined. These modifications include the ability to track serialized components in addition to the full vehicle and the ability to transmit data to a sanitized multi-component database.

SEI SIMS

STRUCTURAL INTEGRITY MONITORING SYSTEM
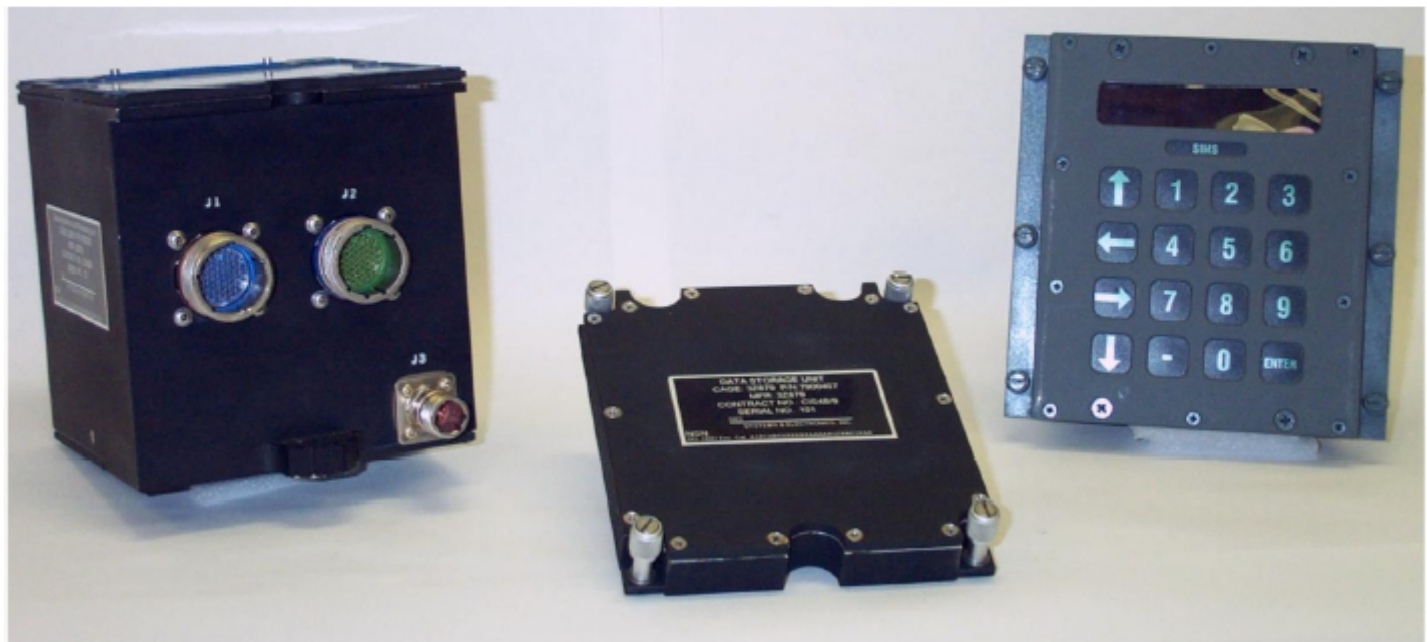
HUMS for UM

This research project is focus upon the use of HUMS and UM technology to derive usage credit for civilian rotorcraft operators. Thus, this is a system that would potential allow operators to fly beyond the nominal hour life of life limited rotorcraft components with equivalent or improved levels of safety. This is done be tracking the actual accumulation of damage to the part instead of assuming a (necessarily conservative) average hourly damage.   Since a failure of such a component could be catastrophic, the end-to-end system must have a very high level of confidence.

System Assurance Level

Since the results of improper usage monitoring could result in a catastrophic failure. The end-to-end system could be considered to be a level A system. Unlike most avionics systems, however, the end-to-end HUMS UM is not real time. It can be shown that individual serial elements of this systems can be level D with a robust mitigation strategy.
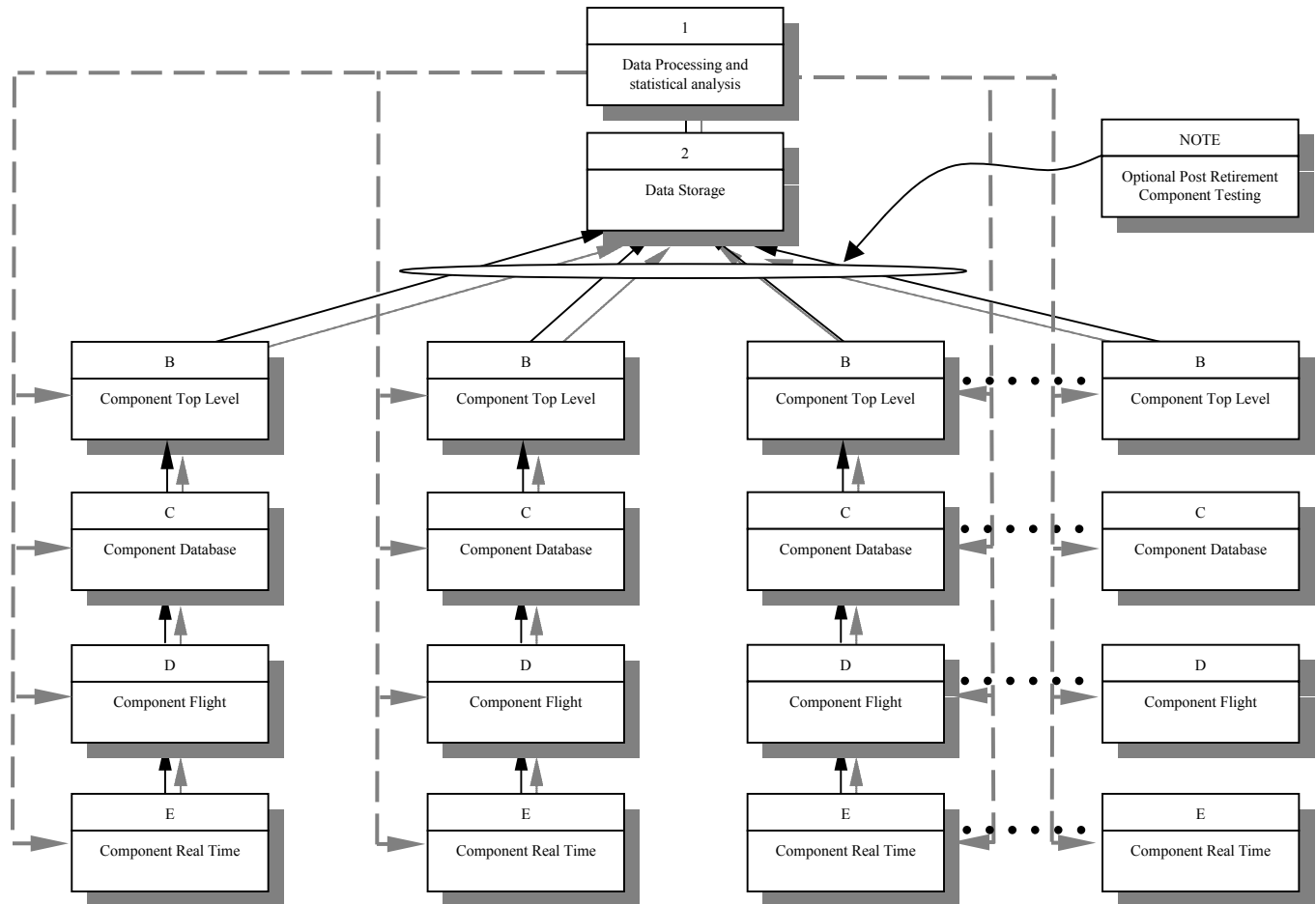
Mitigation

The team has determined in an end-to-end (closed loop) HUMS for UM it is possible to provide mitigation for all perceivable hazards. Thus, high certifications levels for the airborne and ground units is not necessary. This is in line with the desire to use COTS hardware for the ground stations which is unlikely to be certified above level D.

Statistically conservative data can be input for any missing or erroneous data.   Since this is not a real-time system this can be done at multiple levels. This will assure that all data is within statically limits. At first these limits will not be well defined. As the database grows confidence will increase and maximum life extension can be realized.
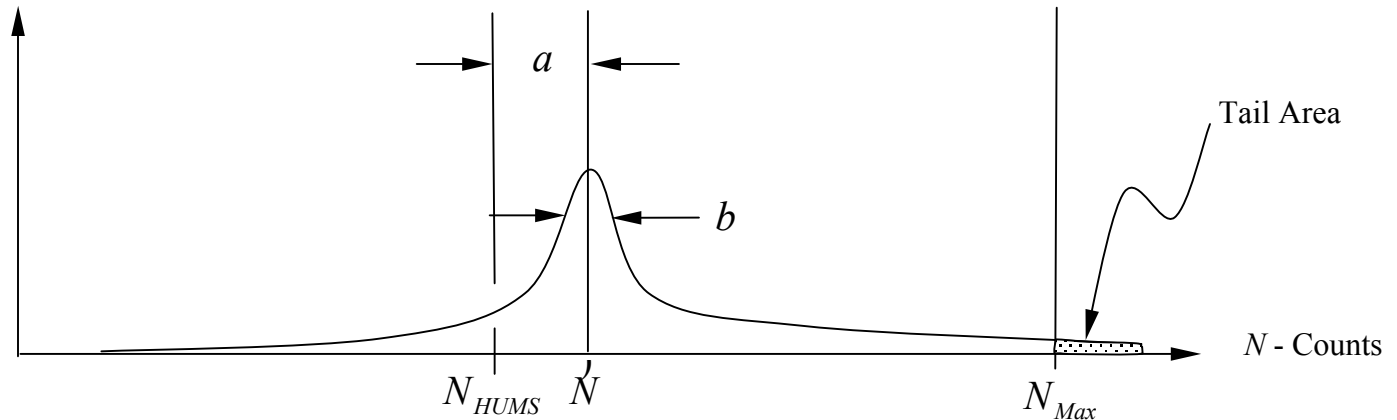
Closed Loop System

Mitigation Example

A maximum number of counts can be determined from historical statistics on rotorcraft operation

Tracked Parameters

There will be several key parameters and databases in the end-to-end HUMS UM.

- Equivalent hours
  - A single number that represents the actual life of the component
  - Must be common between users

- Component database
  - A database that spans all of the flights of the component and tracks crucial statistics

- Multi-component database
  - A top level database that generates the data used to determine values in the equation of equivalent hours.
  - Allows for fleet analysis and trend analysis
  - Should be in a "sanitized" data warehouse.

Concerns

The primary concern for the implementation of a real HUMS UM is the definition or functionality of equivalent hours. The equivalent hours must have the following traits:

- It must represent the actual fatigue on the component
- The definition must be common to all users

These are both difficult as there are no minimum standards in the public domain. OEM's comply with there own design criteria which is proprietary.

UM may not initially be able to extend the life of components. As a public domain database on typical load conditions is populated, however, life extension will be possible.

Next Phase

The next phase of this contract (October 2006) is the assessment of applicable technologies and a strategy for refining, implementing and validating the selected usage monitoring and flight regime recognition algorithms and software.

Years 2 and 3

- Year 2 will have the development of the software and hardware HUMS UM prototype and bench testing. This prototype will be an out growth of the SEI SIMS.

- Year 3 will include flight testing of the prototype system and mock certification of the device.

  - Flight testing will include 20 hours in a fixed wing aircraft
  - Followed by 10 hours in a reciprocating engine rotorcraft with analog instruments
  - Then, several hours of testing in a turbine rotorcraft with access to bus data in addition to analog inputs

Areas of Interest

The team is currently seeking OEMs that are will to participate in this project. Of particular interest is participation from Bell and/or Schweizer (Sikorsky). We are looking for information on any life limited parts to enhance the realism of the UM certification.